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Group Versus Individual Training and Group Performance: The Mediating Role of Transactive Memory

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The task performance of laboratory work groups whose members were trained together or alone was investigated. At an initial training session, subjects were taught to assemble transistor radios. Some were trained in groups, others individually. A week later, subjects were asked to recall the assembly procedure and actually assemble a radio. Everyone performed these tasks in small work groups, each containing three persons of the same gender. Subjects in the group training condition worked in the same groups where they were trained, whereas subjects in the individual training condition worked in newly formed groups. Groups whose members were trained together recalled more about the assembly procedure and produced better-quality radios than groups whose members were trained alone. Through an analysis of videotape data, the mediating effects of various cognitive and social factors on the relationship between group training and performance were explored. The results indicated that group training improved group performance primarily by fostering the development of transactive memory systems among group members.

Training is used widely in organizations. Estimates of the amount that American corporations spend annually on training range from \$30 billion to \$100 billion (Baldwin & Ford, 1988; "Labor Letter," 1991). And this amount is likely to increase as a result of changes in the nature of work and characteristics of the work force (Goldstein, 1989, 1991; "Labor Letter," 1992; Webb & Smith, 1991).

Training programs can be very helpful. In a meta-analysis of the effects of various interventions on worker productivity, Guzzo, Jette, and Katzell (1985) found that interventions designed to enhance productivity through learning, including training programs, had strong positive effects overall. However, there was also considerable variability in the effectiveness of different training programs. Workers cannot always apply the knowledge and skills acquired in training programs to their jobs (Georgeson, 1982), and many examples of training programs that failed to improve worker productivity can be found (e.g., Baldwin & Ford, 1988; Goldstein, 1986; Wexley & Latham, 1981). A few researchers have even reported that investments in training can lead to productivity losses rather than gains (e.g., Galbraith, 1990; Hayes & Clark, 1986).

The real issue, then, is to specify the conditions under which training programs enhance job performance. Researchers are beginning to identify some of these condi-

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tions (Burke & Day, 1986; Guzzo et al., 1985). Although many factors may be important, one critical factor is the *fidelity* of training programs. Fidelity refers to the degree of similarity between workers' experiences during training and their experiences on the job. In general, training programs with greater fidelity are more likely to improve job performance, because they facilitate the transfer of knowledge from training to the job site.

One important factor that may weaken the fidelity and thereby limit the effectiveness of training programs is their emphasis on individual learning. Workers are often trained individually or in large cohorts whose members do not work together. Participants in these training programs generally work on their own (guided by an instructor) to learn new procedures. Afterward, they are assigned or return to job sites, where those procedures can be applied. But the work at those job sites is often performed by groups of people (Argote & McGrath, 1993), whose procedures may differ from those taught during training. Such differences can arise from variation over time in the content of training programs or from the emergence among group members of shared views about how their work should be performed (Levine & Moreland, 1991; Salas, 1993). In either case, misunderstandings, coordination problems, and interpersonal conflicts are likely.

Some corporations have begun to acknowledge the limits of individual training. Ray Stata of Analog Devices argues that training employees in their work groups is more effective than training them individually (Stata, 1989). John Seely Brown of Xerox believes that most learning in organizations takes place in groups (Brown & Duguid, 1991). And the military is investing considerable resources in training group members together as well as alone (Andrews, Wang, & Bell, 1992; Morgan, Glickman, Woodard, Blaiwes, & Salas, 1986).

Despite this enthusiasm for group training, only a few empirical studies have actually compared the performance of work groups whose members were trained together or alone (see Dyer, 1985, for a review), and the results of these studies are quite mixed. Some researchers (e.g., George, 1967) have found that group training is superior to individual training, whereas others (e.g., Briggs & Naylor, 1965) have found that group training is inferior. Several researchers (e.g., Laughlin & Sweeney, 1977) have found no difference at all. These divergent findings are puzzling, and their interpretation is further clouded by methodological problems and a general lack of theory. Clearly, further research is needed to determine whether group or individual training produces better group performance. Several recent reviews of the training literature have called for such research (e.g., Druckman & Bjork, 1991).

The present research was designed to clarify the effects of group versus individual training on group performance. We propose and test a theoretical account for why group training should be superior to individual training. That account is based on Wegner's (1986) notion of *transactive memory*. According to Wegner, shared experiences often lead groups of people to encode, store, and retrieve relevant information together. As a result, a transactive memory system can develop within the group. This system is a combination of the knowledge possessed by particular group members and an awareness of who knows what. A transactive memory system is useful because it can serve as an external storage device (like a library or computer) for everyone in the group. Individual group members are thus able to locate and retrieve information that might otherwise be unavailable to them.

An example may help to clarify transactive memory systems. Imagine a group of people who work together at assembling radios for a small consumer electronics firm. The knowledge and abilities of these workers probably overlap considerably, which can be valuable in situations where one worker must cover for another. But workers are not clones; there is always some variability in the knowledge and abilities of group members. For example, one worker may know more than the others about electronics, whereas another worker is especially adept at connecting certain radio components. If group members are unaware of such expertise, they cannot easily take advantage of it (see Stasser, 1992). But if a transactive memory system exists, so that each group member knows the strengths and weaknesses of his or her coworkers, then the group can make better use of its human resources.

Only a few researchers have investigated transactive memory systems. Giuliano and Wegner (described in Wegner, 1986) studied the operation of such systems within dating couples. Each couple in their study was presented with many items of information (e.g., "The Kaypro II is a personal computer") representing various domains of expertise (e.g., computers). Each person's beliefs about who was more expert in each domain (self, other, both, neither) were measured, and the amount of time available for studying the items was manipulated to give each partner an advantage over the other on some items. The ability of each person to recall the items was then assessed. The results showed that items were more likely to be recalled when they represented domains of self- rather than other-expertise and when they were studied longer. Perceived expertise and study time also interacted in intriguing ways. For example, when someone had more time than his or her partner to study an item, that item was more likely to be recalled if the

partner's expertise in the relevant domain was believed to be low. But when someone had less time than his or her partner to study an item, the partner's perceived expertise in the relevant domain had no effect on recall. These results suggest that partners collaborated at some level to maximize their collective recall, using perceived expertise and available study time as guides for deciding which items of information each person should remember. Such behavior indicated that a transactive memory system was at work.

Wegner, Erber, and Raymond (1991) studied the operation of natural or imposed transactive memory systems within real or artificial couples. As in the previous study, the subjects were all members of dating couples. Some of those couples were left intact, whereas the members of others were randomly assigned to new partners of the other sex. Once again, each couple (real or artificial) was presented with many items of information representing various domains of expertise. Within some of the couples, responsibility for remembering items from each domain was randomly assigned to one partner or the other, as an attempt to impose transactive memory systems on these couples. Within the remaining couples, however, responsibility for remembering items from each domain was left entirely to the subjects themselves. As before, the ability of each person to recall the items was later assessed. The results showed that real couples recalled more items when they used natural rather than imposed transactive memory systems, perhaps because the latter systems were unfamiliar, confusing, or maladaptive. In contrast, artificial couples recalled more items when they used imposed transactive memory systems. Without some help from the researchers, these "couples" probably had trouble deciding who should remember what, because they lacked any natural transactive memory systems.

If the results of these studies can be extrapolated to work groups, then they have important implications for understanding the effects of group versus individual training on group performance. We believe that training the members of a work group together rather than alone may be helpful because it allows them to develop a transactive memory system. When they are trained together, workers can acquire a common language for describing tasks, divide those tasks among themselves in ways that reflect their abilities and interests, and observe one another while they are actually acquiring task expertise. Because they know who is good at what, the members of such a group can seek information from the right person(s) when problems arise and trust that the information they receive will be correct. Knowing who is good at what also improves coordination within the group, because its members can anticipate one another's behav-

ior and therefore react to that behavior more quickly and easily. Group training thus provides workers with a valuable resource—a transactive memory system—that facilitates knowledge distribution and coordination within the group. This resource should improve the group's performance.

The following experiment compared the performance of groups whose members were trained together or alone, with a special focus on the development of transactive memory systems. We hypothesized that:

1. Groups whose members are trained together rather than alone will recall more about how to perform a task.
2. Groups whose members are trained together will perform that task more quickly and accurately than groups whose members are trained alone.
3. Groups whose members are trained together will develop stronger transactive memory systems than groups whose members are trained alone.
4. The development of transactive memory systems will mediate the effects of group training on task performance.

Group training could have other consequences (aside from the development of transactive memory systems) that affect task performance. For example, the performance of a work group often reflects the motivation of its members. There is clear evidence (e.g., O'Reilly & Caldwell, 1979; White & Mitchell, 1979) that motivation depends not only on the objective characteristics of whatever tasks someone performs but also on that person's subjective evaluations of those tasks. These evaluations are often shaped by social influence processes within a work group (see Salancik & Pfeffer, 1978)—processes that should operate more strongly among workers who are trained together rather than alone. Another factor that might be important is the level of cohesion within a work group. Several studies have shown that more cohesive groups exhibit better task performance (Evans & Dion, 1991; Keller, 1986; Murdock, 1989). Group training may strengthen cohesion, because workers who are trained together rather than alone spend more time with one another, share more common experiences, and so on. Finally, social identity theory (Tajfel & Turner, 1986) suggests another way in which group training might affect task performance. According to that theory, people derive part of their self-esteem from the groups to which they belong. A general desire to maximize self-esteem leads to a preference for membership in more successful groups, especially among individuals whose social identities are stronger (see Wilder, 1986). Workers who are trained together rather than alone probably identify more strongly with their groups. If so, then they may be more concerned about improving the performance of those groups.

All three of these factors—task motivation, group cohesion, social identity—are clearly worth exploring, because they represent alternative ways in which group training might improve task performance. While measuring various cognitive factors associated with the operation of transactive memory systems, we consequently obtained measures of these social factors as well. Those measures allowed us to investigate alternative explanations of differences in performance between groups whose members were trained together or alone.

METHOD

Subjects

Ninety students (66 males and 24 females) enrolled in undergraduate business courses at Carnegie Mellon University participated in the experiment to meet course requirements. Half of the sample was randomly assigned to an individual training condition, half to a group training condition.

Task

Subjects were required to assemble the AM portion of an AM/FM radio. This task was chosen to simulate the type of work found in many manufacturing organizations. Radio kits were purchased from the Tandy Corporation (Model 28-175). Each kit included a circuit board and dozens of mechanical and electronic components (e.g., resistors, transistors, capacitors). The circuit board contained prepunched holes with special symbols indicating where different components should be placed. Assembling just the AM portion of the radio required subjects to insert dozens of components into different places on the circuit board and then to connect each component to the others in the proper manner. No special tools for performing this task were provided.

Procedure

The experiment was carried out in two phases. During the first phase, subjects were trained to assemble the radio. This training was conducted either individually or in groups. In the group training condition, subjects were randomly assigned to small groups for training. Each group contained three subjects of the same sex. There were 10 male groups and 5 female groups in the group training condition.

When subjects arrived for the first phase of the experiment, they were told that our research examined how training can affect work group performance. Subjects were then given an overview of the experiment so that they knew what to expect during each phase. In particular, all subjects knew that they would later be asked to work in groups, whose performance would be videotaped and evaluated. Subjects in the individual training

condition did not know who would belong to their groups, whereas subjects in the group training condition expected to remain in their current groups. Subjects were promised that members of the best work group would receive a prize of \$20 per person.

The same basic training was provided to subjects in the two conditions. The experimenter began by demonstrating how the radio's components should be placed on the circuit board and connected to one another. This demonstration lasted about 15 min, and subjects were allowed to ask questions about the radio while the experimenter assembled it. Next, the subjects were given up to 30 min to practice assembling the radio themselves. No individual or group was allowed to assemble more than one radio during this practice period. Finally, the experimenter reviewed with the subjects every component and connection in the radio they had produced, identifying any errors and describing how such errors could be corrected.

The second phase of the experiment, in which subjects' ability to assemble the radios was tested, occurred 1 week later. During this phase, all subjects worked together in groups. Subjects who were trained individually were now assigned randomly to small groups, each containing three persons of the same sex. There were 12 male groups and 3 female groups in this individual training condition. Subjects who were trained as groups remained in those same groups.

Subjects in the two conditions were tested in exactly the same way. First, the members of each group were asked to recall together (as a group) how the radio should be assembled and then record the assembly procedure on a single piece of paper. Up to 7 min was allotted for this free recall task. During that time, subjects talked freely with one another, but they could not consult the experimenter or examine any radios or components. Next, each group was given up to 30 min to actually assemble a radio. The subjects were told to work as quickly as possible but also to make as few errors as possible. While working on the radio, subjects could not consult the experimenter, nor could they examine their own recall sheet. Every group's performance was recorded on videotape, with the subjects' permission.

After assembling their radio, the subjects in each group were given 10 min to complete (individually and privately) a brief questionnaire. This questionnaire requested several items of biographical information, including the subject's age, sex, college major, and prior familiarity with the other group members. Measures of subjects' beliefs about the task (complexity, difficulty, enjoyment) and their group (cohesion, cooperation, role differentiation, memory differentiation) were also included. Afterward, subjects were debriefed, thanked for their participation, and dismissed.

RESULTS

Three measures of group performance were available from the testing phase of the experiment. First, we measured how well each group remembered the procedure for assembling a radio by reviewing its recall sheet and counting the steps in that procedure that were recorded correctly. Higher scores on this measure indicated better group performance. Second, we measured how well each group actually assembled its radio by examining that radio and counting the misplaced or misconnected components it contained. Higher scores on this measure indicated poor performance by the group. (These scores could have been divided by the number of radio components that each group used, but every group used all the components it was given, and so this alternative measure would have correlated perfectly with the simpler one that we used.) Finally, we measured how quickly each group assembled its radio by recording the number of minutes that it took to complete the task. Higher scores on this measure again indicated worse performance by the group.

A summary of the scores earned on all three of these performance measures by groups from the two training conditions can be found in the top portion of Table 1. The results for procedural recall supported our first hypothesis. As we predicted, groups whose members were trained together remembered significantly more about how to assemble a radio than groups whose members were trained alone, $t(28) = 3.08, p < .01$. The results for assembly errors supported our second hypothesis. As we predicted, groups whose members were trained together made significantly fewer errors while assembling a radio than groups whose members were trained alone, $t(28) = -3.30, p < .01$. Our second hypothesis, however, was not supported by the results for assembly time. Groups whose members were trained together or alone took about the same amount of time to assemble a radio, $t(28) = 0.32, \text{n.s.}$

Several regression analyses were performed to determine whether support for our hypotheses varied as a function of the subjects' gender or their prior familiarity with one another. To investigate gender, we regressed each group's performance on dummy variables representing its gender, training condition, and the interaction between gender and training condition. This analysis was performed three times, once for each performance measure. No significant ($p < .05$) interactions between gender and training condition were observed in any of these analyses. This suggests that the support for our hypotheses was equally strong among male and female groups. To investigate prior familiarity, we regressed each group's performance on the mean number of other group members that each subject knew prior to the experiment, a dummy variable representing the

TABLE 1: Some Effects of Group Versus Individual Training on Group Performance and Process

Effect	Group Training		Individual Training	
	M	SD	M	SD
Performance measures				
Procedural recall (number of steps recalled)	25.53	6.91	16.40	9.16
Assembly errors	1.93	1.98	5.06	3.11
Assembly time (minutes)	16.11	4.13	15.67	3.24
Process measures				
Memory differentiation	0.80	0.61	-0.87	0.43
Task coordination	0.43	0.90	-0.47	0.93
Task credibility	0.73	0.16	-0.80	0.91
Task motivation	0.01	0.95	-0.01	1.11
Group cohesion	0.26	0.96	-0.29	1.01
Social identity	0.62	0.85	-0.68	0.66

NOTE: Scores on performance measures are based on 30 groups; scores on process measures are based on only 21 groups (11 in the group training condition and 10 in the individual training condition). Scores on the process measures were standardized before analysis.

group's training condition, and the interaction between prior familiarity and training condition. Once again, this analysis was performed three times, once for each performance measure. No significant ($p < .05$) interactions between prior familiarity and training condition were observed in any of these analyses. This suggests that support for our hypotheses was equally strong among groups whose members had different levels of prior familiarity with one another.

Earlier we suggested that both cognitive and social factors could mediate the effects of group training on group performance. The videotapes taken of the groups while they assembled their radios allowed us to measure several such factors. Unfortunately, the sound quality was poor in the videotapes for 9 groups, 5 in the individual training condition and 4 in the group training condition. There was no evidence that these groups differed from the others on any of the performance measures, and so we decided to code only the videotapes from the remaining 21 groups. Two judges, one of whom was blind to the research hypotheses and to each group's condition, coded these videotapes for evidence of these factors. A list of specific behaviors exemplifying each factor was provided to the judges to facilitate their coding. The judges were asked to watch each videotape carefully, keeping these behaviors in mind, and then make an overall rating of the group on each factor.

Three cognitive factors, all of which were assumed to reflect the operation of a transactive memory system among group members, were coded from the videotapes. The first factor was *memory differentiation*, or the tendency for group members to specialize in remembering distinct aspects of assembling the radio. One mem-

ber, for example, might remember where different radio components should be placed on the circuit board, while another one remembered how those components should be connected. Such specialization is, of course, a key feature of transactive memory systems. The judges rated each group on a 7-point differentiation scale, higher ratings indicating a greater degree of memory differentiation among group members. The second factor was *task coordination*, or the ability of group members to work together smoothly while assembling the radio. In groups with stronger transactive memory systems, there should be less need for planning, greater cooperation, less confusion, fewer misunderstandings, and so on. The judges rated each group on a 7-point coordination scale, higher ratings indicating a greater degree of task coordination among group members. Finally, the third factor was *task credibility*, or how much group members trusted one another's knowledge about assembling the radio. This represents another key feature of transactive memory systems—group members already know how much and what kind of information each person possesses. In groups with stronger transactive memory systems, there should be less need to make claims of expertise, better acceptance of any procedural suggestions, less criticism of work by others, and so on. The judges rated each group on a 7-point credibility scale, higher ratings indicating a greater degree of trust among group members while assembling the radio.

Three social factors were also coded from the videotapes, but these factors were not assumed to reflect the operation of any single underlying process. The first factor was *task motivation*, or how eager group members were to win the prize by assembling their radio quickly and correctly. Group members whose motivation is stronger should express more enthusiasm for the task, encourage one another more often, work harder, and so on. The judges rated each group on a 7-point motivation scale, higher ratings indicating stronger motivation among group members. The second factor was *group cohesion*, or the level of interpersonal attraction among group members. Members of more cohesive groups should sit closer together, speak more warmly to one another, and so on. The judges rated each group on a 7-point cohesion scale, higher ratings indicating greater attraction among group members. Finally, the third factor was *social identity*, or subjects' tendency to think about themselves as group members rather than as individuals. This was the only factor for which behavioral counts rather than ratings were obtained. The two judges counted the times that individual personal pronouns (e.g., *I, me, mine, he, she, him, her, his, hers*) and collective personal pronouns (e.g., *we, us, our, ours*) were used while the members of each group assembled their radio. The ratio of collective pronouns to all personal pronouns

(individual and collective) used was then computed to create an index of social identity. Higher scores on that index indicated a stronger sense of social identity among group members.

For each of these factors, an intraclass correlation was computed to evaluate how reliably the two judges coded the videotapes. These correlations ranged from .61 (for memory differentiation) to .96 (for social identity) and were all significant ($p < .05$), indicating adequate coding reliability. Any disagreements between judges were resolved by averaging their ratings together. This procedure took advantage of the fact that both judges coded every videotape (cf. Hill, 1982) but may have allowed ratings by the nonblind judge to bias the results. To explore this issue, we later reran all our data analyses, using only the ratings from the blind judge. The results indicated that averaging the videotape ratings across judges did not affect any of our findings.

A summary of the standardized scores for each of the cognitive and social factors among groups from the two training conditions can be found in Table 1. It should be noted that alternative measures for a few factors (task motivation, group cohesion, and memory differentiation) were available from the questionnaires. Questionnaire and videotape measures of the same factors were significantly correlated ($p < .05$) with each other. We chose to rely on the videotape measures because their validity was probably better and it seemed preferable to measure all six behavioral factors using the same data source.

A series of *t* tests was performed to determine whether videotape scores on the six factors varied significantly across conditions. Our third hypothesis was clearly supported. Transactive memory systems operated much more strongly among groups whose members were trained together rather than alone. Groups whose members were trained together thus exhibited significantly greater memory differentiation, $t(19) = 7.17$, $p < .01$, task coordination, $t(19) = 2.24$, $p < .05$, and task credibility, $t(19) = 5.50$, $p < .01$. The effects of group or individual training on the social factors were much weaker. There were no significant differences in task motivation, $t(19) = 0.056$, or group cohesion, $t(19) = 1.28$, between groups whose members were trained together or alone. However, when group members were trained together, they did exhibit significantly stronger social identities, $t(19) = 3.87$, $p < .01$.

These results suggest that any of the cognitive factors, and one of the social factors (social identity), could have mediated the observed effects of group training on group performance. To test our fourth hypothesis, we carried out two sets of regression analyses. The only performance measure examined in these analyses was assembly errors. Neither the cognitive nor the social

factors we measured could have mediated the effects of group training on procedural recall, because that performance measure was assessed before the videotapes were made. And because group training had no effects on assembly time, any possible mediation of such effects was excluded. Following procedures suggested by Baron and Kenny (1986), each set of analyses tested whether (a) group training significantly affected group performance, (b) group training significantly affected a potential mediator from the videotape data, and (c) the effects of group training were significantly reduced when that mediator was included as an additional predictor of group performance. All three findings were necessary to confirm mediation.

The first mediator we explored was a composite scale representing each group's average score on the memory differentiation, task coordination, and task credibility measures. These three scores were combined because they were all assumed to reflect the operation of transactive memory systems. Some evidence for that assumption was found in the correlations between these measures, which were all significant ($p < .01$) and positive. Coefficient alpha for the composite scale was .96, indicating a high degree of internal consistency. As we expected, scores on this composite scale were significantly higher, $t(19) = 6.96, p < .01$, among groups whose members were trained together rather than alone.

We began our mediation analysis by regressing each group's assembly errors (P) on its training condition (T). A dummy variable (0 = individual training, 1 = group training) was used to represent training condition in this and other regression analyses. The first regression equation, $P = 6.10 - 4.28T$, accounted for about 42% of the variance and was significant, $F(1, 19) = 15.66, p < .01$. As we reported earlier, groups whose members were trained together made fewer errors while assembling their radios. We then regressed each group's transactive memory (TM) score on its training condition. This regression equation, $TM = -0.87 + 1.66T$, accounted for about 70% of the variance in the transactive memory scores and was also significant, $F(1, 19) = 48.46, p < .01$. As we reported earlier, transactive memory systems were stronger among groups whose members were trained together. Finally, we regressed each group's assembly errors on both its training condition and its transactive memory score. This regression equation, $P = 3.92 - 0.12T - 2.52TM$, accounted for about 57% of the variance and was significant, $F(2, 18) = 14.65, p < .01$. The coefficient for transactive memory was significant, $t(19) = -2.82, p < .05$, but the coefficient for training condition was not significant, $t(19) = -0.07$. This suggests that the transactive memory systems mediated the effects of group training on group performance, because when variability on the transactive memory measure was taken into account,

groups whose members were trained together no longer performed better than groups whose members were trained alone. Our fourth hypothesis was thus supported.

In a second set of analyses, each group's social identity score was tested as a potential mediator. Once again, we began by regressing each group's assembly errors on its training condition. Then we regressed each group's social identity (S) score on its training condition. This regression equation, $S = -0.68 + 1.30T$, accounted for about 41% of the variance in social identity scores and was significant, $F(1, 19) = 15.03, p < .01$. As we reported earlier, groups whose members were trained together had stronger social identities. Finally, we regressed each group's assembly errors on both its training condition and its social identity score. This regression equation, $P = 6.80 - 5.61T + 1.02S$, accounted for about 45% of the variance and was significant, $F(2, 18) = 9.25, p < .01$. But this time, the regression coefficient for training condition remained significant, $t(19) = -3.98, p < .01$, whereas the coefficient for social identity was not significant, $t(19) = 1.02$. This suggests that social identity did not mediate the effects of group training on group performance, because when variability among groups on the social identity measure was taken into account, groups whose members were trained together still performed better than groups whose members were trained alone.

DISCUSSION

The results of our experiment suggest that a work group's performance can indeed be improved by training its members together rather than alone. As we predicted, groups whose members were trained together recalled more about how to assemble their radios, and made fewer errors while assembling those radios, than groups whose members were trained alone. However, groups whose members were trained together did not assemble their radios more quickly. Perhaps assembly time was an unsuitable measure of group performance. A review of the videotapes revealed that most of the groups worked at a very rapid pace. This emphasis on speed may have reduced variability on the assembly time measure, thereby obscuring any differences between the training conditions.

We also predicted that stronger transactive memory systems would emerge among groups whose members were trained together rather than alone. Behavioral evidence gathered from the videotapes confirmed this prediction. When the members of a group were trained together, they were more likely to (a) recall different aspects of the task, (b) coordinate their task activities, and (c) trust one another's expertise. These findings represent the first direct evidence that transactive mem-

ory systems can operate within work groups, as Wegner (1986) claimed.

Finally, we predicted and found that transactive memory systems would mediate the effects of training on group performance. Training the members of a group together strengthened that group's transactive memory system, which, in turn, improved its task performance. Training had no direct effects on group performance when these indirect effects were taken into account. However, direct effects of transactive memory systems on group performance were observed, even after differences in training were taken into account. That is, groups with stronger transactive memory systems performed the task better, whether their members were trained together or alone. This suggests that other procedures, which may be less difficult or costly than training group members together, might be used to strengthen a group's transactive memory system and thereby improve its performance. For example, the members of a group could be trained individually but then provided with some of the information (e.g., the distribution of abilities among workers) normally found in a transactive memory system. Or a supervisor could impose some structure (e.g., task assignments based on the distribution of abilities among workers) on a group that would produce the kinds of behavior normally associated with a transactive memory system. The latter procedure was used in this way by Wegner et al. (1991) in their study of how natural and imposed transactive memory systems can affect the memories of real and artificial couples.

The fact that transactive memory systems mediated the effects of training on group performance helps to discount two alternative interpretations for our results. One such interpretation involves the role of contextual cues in memory. There is some evidence (Bjork & Richardson-Klavehn, 1989; Davies & Thomson, 1988) that people remember what they have learned better when memory is assessed under the same conditions in which learning occurred. This effect probably occurs because associations arise between various aspects of the context in which material is learned and the material itself. As a result, contextual factors can later serve as cues for retrieving that material from memory.

In our experiment, subjects in both training conditions could have used contextual cues involving the experimenter (e.g., her appearance or demeanor) or the laboratory setting (e.g., its sounds or appearance or temperature) as memory aids. However, another source of contextual cues was also available to subjects who were trained together rather than alone. Perhaps these subjects, whose skills at assembling radios were tested in the same groups where those skills were acquired, used *one another's* appearance or demeanor as memory cues. That

might account for the superior performance of their groups. Note that this interpretation is quite different from our own. A contextual cues interpretation requires little interaction among group members, whose mere presence during testing may have been enough to help subjects remember how the radios should be assembled. In contrast, interaction among group members is essential for a transactive memory interpretation, which claims that people consulted one another during testing when they lacked information that others were believed to possess about assembling the radios.

Although a contextual cues interpretation of our results is interesting, the available evidence does not support it. When differences in transactive memory among groups were taken into account, the effect of training on group performance was no longer significant. In other words, *other* possible advantages associated with group training, such as providing group members with additional contextual cues, did not have much impact on group performance. Of course, the effects of contextual cues on group performance could be controlled through procedural rather than statistical means. In future research, we may modify the individual training condition so that group members are trained to assemble radios at the same time but cannot talk to one another, work together, or obtain information about one another's performance. This would allow contextual cues to operate in both the individual and group training conditions but still limit the creation of transactive memory systems to the group training condition.

A second alternative explanation for our results involves the role of group development in group performance. Group members who were trained together rather than alone spent much more time with one another, shared more work experiences, and so on. As a result, their groups probably attained higher levels of development (see LaCoursiere, 1980; Tuckman, 1965), resolving some of the problems (e.g., anxieties about acceptance, interpersonal conflicts) that can plague newer groups. Perhaps the superior performance of groups whose members were trained together reflected their developmental progress rather than their transactive memory systems.

This interpretation of our results is interesting as well, but the available evidence does not support it either. Group development is another potential advantage of group training. Although transactive memory systems may be found more often in older groups, they need not arise there. That is, a group may or may not develop an effective system of transactive memory as time passes. Group development and transactive memory are thus correlated but distinct phenomena. Our finding that training had no significant effects on group performance when differences in transactive memory among

groups were taken into account thus becomes relevant once again. As we noted earlier, it means that *other* possible advantages associated with group training, such as fostering group development, did not have much impact on group performance. Two other findings from our research also seem relevant to this issue. First, behavioral evidence gathered from the videotapes allowed us to investigate such social factors as group cohesion and social identity, both of which are associated with group development (Ewert & Heywood, 1991; Kuypers, Davies, & Hazewinkel, 1986; Louche & Magnier, 1978). Yet training had no effects on group cohesion, and although social identity was indeed strengthened by training group members together rather than alone, social identity did not mediate the effects of training on group performance. Second, some of the groups we studied contained members who already knew one another prior to the experiment. Yet these groups, which probably developed more quickly and easily, did not perform any better than groups whose members were complete strangers. All these findings indicate that group development was not responsible for the superior performance of groups whose members were trained together rather than alone.

The results of our experiment suggest many directions for future research, but we are especially interested in several factors that might moderate the effects of group training on performance. We do not believe that groups whose members are trained together will always perform better than groups whose members are trained alone. But when will the advantages of group training be especially strong or weak? Several factors could be important in this regard. These factors include characteristics of the group, the task that the group performs, and the environment in which the group operates.

The composition of a work group (see Moreland & Levine, 1992) may be one important moderating factor. Some groups are relatively homogeneous—their members come from similar backgrounds, have comparable abilities, and share interests. But other groups are more heterogeneous, and the performance of these groups can suffer when differences among group members produce confusion and conflict (Jackson, 1991). Training the members of a heterogeneous group together rather than alone, so that they can learn to work together more smoothly, may therefore be especially advantageous. Another moderating factor that may be important is a group's task (see Steiner, 1972). Some tasks require little coordination among group members, but other tasks require group members to interact quickly and in complex ways (Argote, 1982; Murnighan & Conlon, 1991). Training the members of a group together rather than alone may be especially advantageous for tasks with greater coordination requirements. Finally, the amount

of stress that a group experiences may also be an important moderating factor. Stressful working conditions, arising from time pressure, competition with other groups, or even physical danger, affect many groups. Staw, Sandelands, and Dutton (1981) have suggested that groups often respond to such conditions by becoming more "rigid." This rigidity involves a restriction in information processing (e.g., narrower or reduced attention) as well as a constriction in control (e.g., reliance on tradition or centralized power). More rigid groups generally perform less well, unless their members have developed strong and effective work routines. Such routines are more likely to be found in a group whose members were trained together rather than alone (see Goodman & Shah, 1992; Hall & Williams, 1966). This suggests that group training may be especially advantageous when a group must operate under stressful working conditions.

Some theorists (see Druckman & Bjork, 1991) have argued that group training is an interesting notion but is probably impractical because of turnover. Every group eventually loses some of its members, whose departure could damage the group's transactive memory system, especially when they possess unique knowledge or abilities. Indeed, Wegner, Giuliano, and Hertel (1985) have described with great poignancy the distress that people feel when broken relationships leave them unable to recover valuable information that their group once possessed. This suggests that turnover may actually have more harmful effects on groups whose members were trained together rather than alone. Of course, there may be ways to minimize these effects, such as building greater redundancy into the group's transactive memory system or selecting newcomers who match as closely as possible the oldtimers they are replacing. Moreland and Levine (1992) have also described several ways in which the socialization of newcomers might be altered to help them participate in a group's transactive memory system more quickly and easily. These ideas seem worthy of further investigation.

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